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Oceanit Laboratories, Inc.
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EROSION MANAGEMENT PROGRAM RECOMMENDATIONS FOR HAWAII

Submitted to:
HAWAII COASTAL ZONE MANAGEMENT PROGRAM
OFFICE OF STATE PLANNING

July 1990

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July 1990

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EXECUTIVE SUMMARY

The Hawaii Coastal Zone Management (CZM) program, through the Office of State Planning (OSP), requested Oceanit Laboratories, Inc. to support the development of an Erosion Management Program (EMP) by analyzing relevant information and recommending program guidelines and objectives. Additionally, we were requested to recommend a suitable method for the collection of coastal information (e.g., erosion rates), which would later become an integral part of the EMP.

Hawaii's land-use process is commonly referred to as "complex." This holds true for coastal activities. The present management program is geared to address coastal erosion concerns as a tangent to a land-use process. However, coastal erosion is not only a land-use issue, but a resource management issue. Analysis of Hawaii's existing programs that manage activities related to coastal erosion revealed that the current regulatory scheme operates in a piecemeal fashion that gives rise to various problems, including: inconsistent management strategies; lack of uniform policy guidelines for dealing with illegal or non-conforming structures and encroachment of state-owned land; complex and unresponsive regulatory processes with overlapping regulatory functions between agencies; and lack of comprehensive planning. Planning for erosion management is further impeded from a lack of data on coastal erosion phenomena and land-use activities in the coastal zone, which hinders the effective execution of regulatory efforts.

Recommended actions include coordinating federal, state and county erosion management funding to develop a comprehensive data collection program; develop a comprehensive erosion management plan; and consolidate jurisdiction over the shoreline area to place the bulk of the regulatory powers in a separate agency or division, e.g., "Office of Beaches."

Many other states and countries have regulatory authorities that handle erosion problems. However, each program is uniquely designed to address their erosion problems, which directly reflect on socio/economic values. In places where erosion represents a large economic loss, proportional monies are spent on the problem.

The recommended EMP mission for Hawaii is "conserve beaches and minimize erosion," which is sufficiently broad to accommodate many of the complex matters associated with the problem; however, it is specific enough to emphasize the need to conserve beaches and minimize the loss of coastal property through erosion. The mission is further clarified with mission guidelines, objectives, goals and a proposed schedule. These details are recommended as a starting point for the development of an EMP.

Erosion monitoring methods are a direct reflection of the tradeoffs between social and economic values. Various methods are available; however, costs very widely. In Hawaii initial information can be extracted from historical maps and aerial photographs already available. The accuracy of the results will depend on the accuracy of maps and methods adopted for information extraction. The methodology most suited for Hawaii requires aerial photographic monitoring with ground measurements at places that are of high risk or high need. High accuracy measurements cost more, but are only needed in certain high risk areas. Initial data collection is expected to be costly; however, ongoing data collection maintenance will be considerably less.

All erosion control management activities have strong social, economic and legal components. Land ownership, recreational requirements, beach access and proximity to public facilities must be considered when evaluating impacts from a proposed development. It is important to realize that the success of an erosion management plan is highly dependant on the degree of public participation while evolving the plan. Issues connected with erosion, e.g, rights of private land owners and potential legal involvement, discourage regulatory agencies. These tradeoffs between individual rights and public benefit are unavoidable; however, a method to evaluate potential economic losses and gains to all parties involved, as well as other related mitigation, is expected to be a major tool for resolving these unavoidable conflicts.

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I. INTRODUCTION

A. BACKGROUND

In January 1990 the State of Hawaii Coastal Zone Management Program (HCZMP) issued a request for proposals to perform studies related to the development of erosion management recommendations. Thereafter, Oceanit Laboratories, Inc. (OLI) was selected for execution of the study; in May 1990 an agreement was signed and we formally began work.

The Hawaii Coastal Zone Management Program (HCZMP) is based on the Hawaii Coastal Zone Management (CZM) law Chapter 205 A, Hawaii Revised Statutes. Objectives and policies of the law address recreational, historic, scenic and open space resources, coastal ecosystems, economic uses, coastal hazards and managing coastal development. Other state statutes that authorize regulations, plans and review processes for activities that affect Hawaii's land and ocean environment have either been incorporated in the HCZMP as supporting policies and mandates or, in the case of Federal Agencies, are reviewed for consistency by the State CZM agency.

One of the objectives of the CZM program is to reduce hazard to life and property from tsunami, storm waves, stream flooding, erosion and subsidence. Policies set-down under this objective include the following:

- o Develop and communicate adequate information on storm wave, tsunami, flood, erosion and subsidence hazard.
- o Control development in areas subject to storm wave, tsunami, flood, erosion and subsidence hazard.
- o Ensure that developments comply with requirements of the federal flood insurance program.
- o Prevent coastal flooding from inland projects.

Information on hazard intensities, locations and land use constitute an important input (for purposes implementing these policies). Exposure to oceanographic phenomena such as waves, currents, storms, tsunamis and sea level elevations as well as bathymetric relief of the nearshore sea bed, and the geologic composition of the land strip adjacent to the waterline, contribute to the potential erosion hazard faced by the coastal land. The net effect from these forces can be erosion of coastal land and flooding of low lying areas along the coast. Long-term trends in land loss is an extremely important parameter that is needed for effective policy implementation and to control development in the hazard areas.

B. OBJECTIVE

The purpose of this report is to recommend a uniform method for monitoring long-term erosion trends and to develop erosion management recommendations for the State of Hawaii that will support the establishment of an erosion management program.

Specific tasks to be addressed herein include the following:

1) Revise the mission and evaluate and prioritize the goals and objectives of the erosion management program.
2) Analyze methods of monitoring and predicting long term erosion trends in terms of cost, accuracy and technical requirements. The analysis will address applicability and usefulness, within the framework of resources and responsibilities of government agencies and compatibility with previous methods used, existing erosion data and the type of erosion in Hawaii.
3) Develop general criteria and guidelines for responding to coastal erosion. Develop general guidelines that can be applied for responding to coastal erosion under various environmental, erosion hazard and ownership circumstances. Analyze socio-economic issues related to erosion such as protection of public versus private rights, and public access.

During the relatively short time available to complete this project several meetings were held with the CZM office and other departments in the City and County of Honolulu and State of Hawaii to discuss the different problems faced by them while implementing erosion management activities and engaging non-compliance actions by coastal property owners.

II. EROSION MANAGEMENT PROGRAM MISSION

The mission of Hawaii's erosion management program should reflect federal, state and county laws governing coastal resource management. Erosion is not an isolated and independent topic, it is one of several factors considered in making coastal resource management decisions.

Since there are presently no clear and direct goals or objectives that guide coastal erosion issues, actions on erosion related matters have lacked resolve and direction. Now, more than ever, there is a need to clarify and strengthen the state's goals relative to coastal erosion.

Hawaii is an island-state with an increasing population base that continues to place urbanization pressures on its shoreline resources. In areas where there are few usable beaches or where population densities are high, shoreline resources have become increasingly rare and valuable. Meanwhile, public dissatisfaction and concern over shoreline encroachment issues has increased.

Erosion issues either directly or indirectly affect important social issues such as:

- o Public access to and along the shoreline.
- o Public recreational use of the shoreline.
- o The loss of private or public property.

Coastal erosion has often been viewed as a natural hazard problem. However, it is in fact both a natural and a man-made problem. For example, the construction of a seawall or groin can permanently alter the adjacent coastline.

Existing coastal erosion management activities are based on regulation of development in the shoreline and nearshore area, thereby limiting development in areas prone to natural erosion hazards. Program planning has not kept up-to-date with current social concerns over shoreline uses, as well as with technological developments in the ocean sciences. Over the years a greater understanding of coastal processes has developed, as well as the effect of man-made structures upon the coastal environment, and alternate techniques or designs for structures affecting the coastal environment.

Hawaii's erosion management efforts reflect various pieces of legislation that address coastal zone management issues. Section 205A-2 (b)[6], Hawaii Revised Statutes, states that one of the objectives of the coastal zone management program is to "reduce hazard to life and property from tsunami, storm waves, stream flooding, erosion and subsidence." The Special Management Area use permit procedure established in Section 205A, Hawaii Revised Statutes implements the state's coastal zone management program through the regulatory process. Furthermore, the state's land use laws act independently to regulate shoreline management issues.

In addition to these laws, other federal, state and county laws have been enacted to establish coastal management regulatory mechanisms. However, despite the relative abundance of tangentially applicable laws, only a handful of core agencies and regulations materially affect the management of Hawaii's shoreline areas.

Since other reports have provided comprehensive overviews of potentially applicable laws, this report will not attempt to duplicate those efforts. Instead, our focus will provide the reader with an overview of the primary regulations that are currently being used to implement shoreline policies that involve coastal erosion issues, as well as provide a summary of the types of problems that exist under the current management system.

A. THE EXISTING MANAGEMENT PROGRAM

The primary actions or approvals that affect regulation of the shoreline area are listed in Table II-1 and Table II-2, and are further described in the narrative that follows.

TABLE II-1

PRACTICAL STATE REGULATORY CONCERNS

APPROVAL	DECISION-MAKING AUTHORITY	PROCESSING/ RECOMMENDATIONS	ENABLING LEGISLATION
Shoreline Certification	Chair, Board of Land & Natural Resources	Land Survey Administrator, Department of Accounting & General Services	Sections 205A-42 and 205A-49, Hawaii Rev. Stat.
Land Disposition	Board of Land & Natural Resources	Land Management Division, Department of Land & Natural Resources	Chapter 171, Hawaii Rev. Stat.
Conservation District Use Application Permit	Board of Land & Natural Resources	Office of Conservation & Environmental Affairs, Dept. of Land & Natural Resources	Chapter 183-41 Hawaii Rev. Stat.
District Boundary Amendment	Land Use Commission	Office of State Planning	Chapter 205 Hawaii Rev. Stat.
Five Year Boundary Review	Land Use Commission	Office of State Planning	Section 205-18 Hawaii Rev. Stat.

TABLE II-2

PRACTICAL COUNTY REGULATORY CONCERNS

APPROVAL	DECISION MAKING AUTHORITY	PROCESSING RECOMMENDATION	ENABLING LEGISLATION
Special Management Area Use Permit	Planning Commission (City Council for Honolulu)	Planning Department (Dept. of Land Utilization for Honolulu)	Chapter 205A <u>Hawaii Rev. Stat.</u>
Shoreline Setback Variance	Planning Dept. (Dept. of Land Util. for Honolulu)	Planning Department (Dept. of Land Utilization for Honolulu)	Chapter 205A <u>Hawaii Rev. Stat.</u>

SHORELINE CERTIFICATION

The shoreline certification procedure serves to standardize the certification of the shoreline statewide, and allows this certified shoreline to be utilized in implementing laws that affect the shoreline. The need for a shoreline certification may arise under several circumstances. For example, a certified shoreline may be required for the following:

- o To obtain a boundary interpretation from the Land Use Commission to determine whether portions of a parcel are located in the conservation district.
- o To determine what portions of a parcel are located within the shoreline setback area.
- o To prepare a metes and bounds description of a shoreline parcel for conveyance purposes, or for purposes of applying for rezoning or a Special Management Area use permit.
- o To obtain building permits to construct on an ocean front property.

LAND DISPOSITIONS

Land disposition issues may arise when shoreline structures intrude upon state-owned lands. In particular, the disposition of an easement may occur where encroachments currently exist, or are proposed to be placed upon abutting state-owned lands.

Administrative rules governing shoreline certifications were adopted in 1988 and have been effective as of December 1, 1988. The certification rules state that a shoreline may not be certified in cases where the owner's property or improvement encroaches upon state land (Section 13-222-19, Shoreline Certifications). The encroachment problem must be resolved with the department before the certification can occur. Certification may be suspended for example, in the situation where an existing seawall was built upon state-owned lands without any type of governmental authorization.

The Division of Land Management is responsible for processing and making recommendations to the Board of Land and Natural Resources on land disposition items. This division has therefore taken the lead in attempting to resolve disputes of this nature that potentially affect state-owned lands. Faced with the difficult problem of resolving these types of issues, the division has drafted and is utilizing objectives, criteria and guidelines for resolving disputes relative to shoreline encroachments on state-owned lands.

CONSERVATION DISTRICT USE PERMIT APPLICATIONS

Unlike the shoreline certification and land disposition processes, the conservation District Use Application ("CDUA") permit process is directly tied to Hawaii's land use laws. A CDUA must be obtained to build a structure upon lands that are located within the conservation district. Chapter 2, Title 13 sets forth the administrative rules of the Department of Land and Natural Resources for governing uses of conservation district lands.

The CDUA often comes into play in the shoreline area since generally, lands makai of the certified shoreline are placed in the conservation district. In addition, many coastal parcels were originally placed in the conservation district at the adoption of the state land use law or during the last boundary review process, to place tighter land use regulations on the coastal areas.

DISTRICT BOUNDARY AMENDMENTS

The State Land Use Commission is responsible for reclassifying land to one of the four state land use districts - conservation, agriculture, rural or urban. This boundary amendment process pertains to coastal erosion issues since the land use classification of the property will ultimately influence the regulatory requirements that the property will be subject to.

Once the property is reclassified to the urban district, the CDUA process is no longer applicable, and if no state-owned land is involved, the state will have no further significant regulatory jurisdiction over the development of the property.

Section 205-2 of Hawaii Rev. Stat., and Section 15-15-20 of the Hawaii Land Use Commission Rules, sets forth the standards that the commission must follow in determining district boundaries. Some of the standards that pertain to lands in the conservation district relate to coastal erosion issues. These include - providing beach reserves, preventing floods and soil erosion, and preserving areas of value for recreational purposes.

FIVE YEAR BOUNDARY REVIEW

Section 205-18 of Hawaii Rev. Stat. requires the Office of State Planning to undertake periodic reviews of the classification and districting of all lands in the State. The first review process must take place within five years of December 31, 1985, and will take place every fifth year thereafter. As part of its review effort, the office may initiate state land use boundary amendments which it deems appropriate.

The last boundary review process took place in 1969. During that review, land use boundaries throughout the state were reviewed. Shoreline conservation was one of the issues that was considered in reviewing the designation of conservation district lands. The consultants that analyzed these boundaries adhered to the concept of the shoreline as a zone rather than a line, and in many portions of the state a conservation district zone was adopted along the coastal area (Eckbo, Dean, Austin & Williams, State of Hawaii Land Use Districts and Regulations Review, 1969). The Office of State Planning is currently conducting a boundary review process.

SPECIAL MANAGEMENT AREA USE PERMIT

Regulation of the Special Management Area ("SMA") was delegated to the counties through Chapter 205A of Hawaii Rev. Stat. Each county was required to establish rules and regulations to govern the SMA use permit procedure.

The SMA permit procedure is applied independently of the zoning. The permit is required if a property is located within a designated SMA area, and if a proposed action qualifies as a "development", pursuant to the statutory definition of that term. The SMA is defined as encompassing the land extending inland from the shoreline on maps filed with the county, or as amended by the county.

The SMA permit procedure does not apply in all instances of coastal development that affect shoreline erosion. The law does exempt certain activities, such as the construction of single-family residences from the SMA permit requirement. In the City and County of Honolulu, most proposals for shore protection structures are exempt from the SMA use permit procedure in Honolulu county, as the county defines the single-family residence exemption as including seawalls to be built on parcels containing a single-family residence.

SHORELINE SETBACK VARIANCE

The Shoreline Setback law established a state-wide setback of forty feet from the shoreline, with a twenty foot setback from the shoreline allowed for smaller lots which met specific criteria. The statute essentially prohibited construction within the setback area, but established a variance procedure that was delegated to the counties to administer.

The statute provides for the granting of variances in cases of hardship or public interest, the construction of shore protection structures for the protection of property and the replacement of nonconforming structures.

B. ANALYSIS

The current regulatory scheme addresses the management of shoreline resources and coastal erosion problems in a piecemeal fashion. This has given rise to numerous problems, which are identified and discussed in this section.

B.1. INCONSISTENT MANAGEMENT STRATEGIES

The establishment of shoreline setbacks, buffer areas or "no-build zones" are important tools in dealing with coastal erosion, and in preserving beaches and lateral shoreline access. Although these are fundamental planning concepts for the coastal areas, there is a lack of consistency and overall strategy in the utilization of shoreline setbacks or zones.

For example, the 1969 state land use district boundary review process sought to establish conservation districts along the coastal areas to provide for added protection of the state's shoreline areas. The conservation district boundaries were established based on four major criteria:

1) Where a road or access way existed at the edge of an agricultural use within reasonable proximity to the shoreline, it was used as the boundary between the Agriculture and conservation districts.
2) Where a vegetation line such as a windbreak or rows of trees more clearly mark the edge of the agricultural practice, this line was used.
3) Where the shoreline is bounded by steep cliffs or a pali, the top of the ridge was used.
4) Where no readily identifiable physical boundary such as any of the above could be determined, a line three hundred feet inland of the line of wave action was used.

Since the last boundary review process was completed, much shoreline land has been taken out of the conservation district. However, the concept of urbanizing land but retaining zones of conservation land along the shoreline area has still been retained on occasion. These conservation zones have not been applied in a consistent manner, and when they have been utilized they have not established uniform zones. Areas contained within the conservation strips have not necessarily followed the criteria outlined above. Rather, development proposals have been reviewed on an ad hoc, case by case basis.

The counties, in particular the City and County of Honolulu, has been grappling with the width of the shoreline setbacks that were originally established by Chapter 205A, Hawaii Rev. Stat. The forty foot setback has been viewed as being inadequate in many instances for effectively controlling coastal erosion problems and addressing beach preservation issues.

The Department of Land Utilization of the City and County of Honolulu recently commissioned a study to develop strategies that would improve the management of the shoreline setback area [12]. This study recommended the establishment of varying setbacks that were calculated based upon a probabilistic model that utilized historical beach transect data. This model provided preliminary setback recommendations that ranged from forty feet to over one hundred feet inland from the shoreline.

The department utilized this study to introduce an ordinance to establish setbacks greater than forty feet on specified beaches, as recommended by the study. The ordinance was opposed by residents of certain affected properties, and to date has not been adopted by the city council.

Both the 1969 boundary review criteria, and the recent DLU study point to the need for a uniform method of establishing and maintaining shoreline setback areas. This method must consider coastal erosion issues as well as other equally important coastal management problems. Technical criteria should be utilized in establishing setbacks or providing for buffer zones in the shoreline area.

B.2. LACK OF UNIFORM POLICY GUIDELINES

Agencies that have the responsibility of regulating the shoreline area are faced with making difficult management decisions absent clear policy direction or guidelines. Permit procedures lack coordinated policy directions and approval criteria.

For example, nonconforming structures such as existing seawalls present numerous problems. Yet, there has been no consistent policy in dealing with such structures.

As discussed earlier in this paper, the shoreline certification process requires that encroachment disputes involving state-owned land be resolved with the Department of Land and Natural Resources prior to certification. Given the lack of policy direction in resolving shoreline disputes, the department drafted, and the Board of Land and Natural Resources subsequently adopted guidelines to establish some consistency in dealing with shoreline encroachment issues.

The department's stated objective in dealing with shoreline encroachment problems is to protect, preserve and enhance public shoreline access and public beach areas. This objective is supported by the following criteria: "If the encroachment serves to protect, preserve and enhance public shoreline access and public beach areas, it may be allowed to remain with appropriate land disposition from this Department. If not, then the encroachment should be removed." Recognizing the difficulties that are encountered in requiring an existing structure to be removed, the request was also made for the assistance of the Department of the Attorney General to pursue legislation as has been adopted in other coastal states, requiring the abutting property owner to remove undesirable encroachments.

The department also adopted specific guidelines to govern the disposition of state land in shoreline encroachment situations. These guidelines allow dispositions to occur:

1) To allow repair work to be done on state-owned land for existing seawalls built within private properties.
2) Where the seawall straddles the private property line and the state land.
3) Where the encroachment does not prohibit public shoreline access and does not take public beach area.

Encroachment disputes may be resolved through the application of these guidelines. However, if a structure fulfills these criteria and is permitted to remain on state land, in all probability a CDUA permit will still be required. Regardless of the fact that the encroachment issue has been resolved with one division of the Department of Land and Natural Resources, a second layer of approval process still exists in the same department within a separate division.

After-the-fact CDUA's are processed in accordance with CDUA guidelines that are set forth in Chapter 2, Title 13. In general, these rules are vague with respect to shoreline issues, and have no relationship to the guidelines that are used to evaluate encroachment issues.

In addition, the counties do not use the same guidelines as the state. Under Honolulu's Shoreline Setback law for example, nonconforming structures in the shoreline area do not need a variance under many circumstances [25].

A lack of consistent criteria to review proposals for new shoreline structures is also evident on all levels of the permit process. From the technical standpoint, the design of a seawall is extremely important and can affect the ultimate impact that the structure will have on the beach in front of and adjacent to the property. However, there are no clear construction or design guidelines to review proposals.

To obtain building permits for a house, building plans must be certified by an engineer and reviewed by the building department. The department would utilize standard professional review criteria for evaluating the adequacy of the structure prior to issuing permits. There is no similar method for evaluating shoreline structures and in particular, seawalls.

The City and County of Honolulu had implemented a certification procedure to attempt to address this problem. Rule 14 of the county's Shoreline Setback Rules and Regulations required that all applications for a setback variance be accompanied by a certification report from a coastal engineer. The report was required to indicate that: "...(1) the structure is needed for safety reasons or to protect the property from erosion or wave damages, (2) the proposed construction is the best alternative of several investigated, and (3) the proposed construction will not cause any adverse effect on or significant change to, the shoreline..."

The DLU faced several problems in implementing this certification requirement. In particular, liability concerns of coastal engineers were so great (liability was high with respect to fees) that it became virtually impossible to find competent engineers to certify a design, with respect to compliance with criteria. Additionally, coastal engineering is a relatively new discipline. There is no license program.

B.3. COMPLEXITY OF REGULATORY PROCESS

The current regulatory process governing the simple construction of a seawall is such a quagmire, that many small landowners resort to the construction of illegal seawalls. For example, a landowner that is simply trying to build a seawall may be subjected to obtaining a: shoreline certification, a Shoreline Setback Variance, a SMA use permit (not applicable in Honolulu), and if the seawall is in the conservation district, a CDUA.

Many of these permit procedures are unduly complicated, time consuming and costly, particularly for the small landowner that is unfamiliar with the regulatory process. The overlapping regulatory functions between the state and the county, and even between state agencies in the same department, can present an overwhelming situation to the general public.

The shoreline certification rules have added to this jurisdictional confusion since the certification rules allow the department to suspend certification in cases where there are potential encroachment issues. This suspension affects the entire permit process since the county is then unable to establish the setback line to determine whether a variance is required. The Office of Conservation and Environmental Affairs is unable to determine whether a CDUA is required. The entire permit process is stalled until the issue can be resolved with the Division of Land Management.

Problems with the shoreline certification procedure may also affect actions that are not being proposed in the immediate shoreline area. For example, suspension of certification may be triggered when there is a questionable existing seawall and improvements are being proposed on portions of the parcel that are mauka of the shoreline. These non-shoreline improvements may be affected since the suspension may affect zoning, SMA permit, subdivision or building permit approvals.

The recent ordinance that was proposed to increase the shoreline setbacks on Oahu also contained a provision that sought to circumvent this problem. The ordinance would have allowed the Director of the DLU to waive the certified shoreline survey for a development located more than fifteen feet landward of the setback.

In 1989 Section 205A-45, Hawaii Rev. Stat. was amended to allow the counties to expand the setback area to include the area between mean sea level and the shoreline. This area of the beach which extends seaward of the shoreline falls under the jurisdiction of the Department of Land and Natural Resources. Although to date, none of the counties have expanded their setback areas to include this portion of the beach, this statutory amendment raises the potential for further overlapping jurisdictions within the regulatory process.

B.4. LACK OF COMPREHENSIVE PLANNING

A lack of comprehensive data on coastal areas has stifled the development of a comprehensive plan for coastal erosion and coastal resource management, and has added confusion to the regulatory process.

It would have been impossible to establish meaningful development policies and criteria for Hawaii's land use laws without obtaining an accurate inventory of the land uses in the state. Establishing a regulatory system to control development on the land, absent an adequate inventory of land use information would have been foolish.

Yet, this is almost the situation that exists with regard to coastal erosion and in the larger picture, with regard to coastal resources management. There is no comprehensive inventory of the information regarding the type of issues that affect coastal uses - public use and public access, coastal views, and historical shoreline movement.

The lack of a comprehensive inventory of shoreline measurements hinder planning and regulatory efforts. The shoreline location is analogous to the Land Use Commission's boundary maps. Without the boundary maps, the state cannot determine jurisdiction between the county and the state. For example, if the property is in the conservation district it falls under state jurisdiction; if the boundary places it within the urban district it falls under county jurisdiction.

There are many instances of illegal structures in the shoreline area. Enforcement powers have been inadequate to address these illegalities and are hampered by the lack of comprehensive and coordinated plans with regard to shoreline uses.

Landowners may challenge enforcement efforts through legal mechanisms. These claims are all the more difficult to prosecute, absent an overall justification for the action. Without a comprehensive plan and supportive justification, enforcement efforts will be disjoint.

B.5. RECOMMENDATIONS

Based on the analysis of the existing management program, the following actions are recommended:

1) Prioritize and coordinate federal, state and county erosion management funding to develop a comprehensive data base on coastal areas statewide. Necessary components of the database are discussed in Section III of this report.
2) Develop a comprehensive coastal erosion plan for the state. Since coastal erosion issues affect other pertinent shoreline issues, the coastal erosion plan would be one component of a shoreline plan. This plan should consider the items that are discussed in this report.
3) Consolidate jurisdiction over the shoreline area to place the bulk of the regulatory powers in one state agency. The most logical way to develop this authority may be to establish a separate division or "Office of Beaches" within an existing agency that already handles these matters, such as the Department of Land and Natural Resources. The Office of Beaches would be responsible for:
   a) Update the coastal database discussed in item 1 on a periodic basis.
   b) Regulate proposed shoreline uses in accordance with the comprehensive coastal erosion plan.
   c) Conduct enforcement matters relative to illegal uses or structures.
   d) Implement beach replenishment actions or shore protection measures, where necessary.

These recommendations cannot be implemented unless the state decides to make the preservation of its beaches a priority. The recommended course of action will require a commitment of money and manpower. It will require hiring persons who are technically competent with regard to coastal erosion and other shoreline problems.

The most difficult recommendation to implement will be the creation of a new authority. This action will obviously be controversial as it will require restructuring the current distribution of jurisdiction that is spread between the various county and state agencies. Yet, without this consolidation, it will be extremely difficult to effectively address the various beach conservation problems that exist.

C. MISSION BACKGROUND

Erosion management policy decisions are the responsibility of the Coastal Zone Management (CZM) program, which is administered by the Hawaii Office of State Planning (OSP). At present, the State of Hawaii does not have a coherent erosion management program.

Erosion effects all of the Hawaiian Islands and becomes a serious problem when it occurs around populated areas, such as parts of Maui, Kauai, Hawaii and Oahu. Sandy beaches are a resource that supports various sectors or the State; this resource is becoming scarce. Clearly, Hawaii would benefit from a comprehensive erosion management program.

Many other states have CZM programs that address erosion similarly to Hawaii (approximately 29 states have CZM programs [23]). Some states have gone further and have developed specific legislation or other mechanisms to deal with coastal erosion. For example, Virginia has the Shore Erosion Control Act and subsequently set up the Shoreline Erosion Advisory Service (SEAS) to assist property owners in preventing erosion [21].

Nineteen states use direct regulatory authority to mitigate damage from coastal hazards. Most states have established a threshold erosion standard of 1 foot per year to define a high hazard area [24]. Each state that administers an erosion management program is unique, and reflects a trade-off between social and economic values.

MICHIGAN

Michigan implements its management strategy for high-risk erosion through the following [24]:

- o Identification of high-risk erosion areas. Only those receding at a long-term average of 1 foot or more per year are considered high risk.
- o Designation of high-risk erosion areas. This includes much community participation. After reviewing community input and other relevant information a high-risk designation is made.
- o Implementation. Michigan emphasizes a non-structural approach by requiring setbacks.
  - alert owner or buyer of shoreline property to the potential of erosion hazard
  - setback is designed to protect permanent structures for a period of 30 years
  - Building requirements. High risk designation requires that the structure be setback a distance that would protect it from erosion damage for 30 years.
  - Special exceptions are made if a parcel was established prior to high-risk erosion designation and lacks adequate depth to provide the minimum required setback. The parcel is then referred to as a "substandard lot." A special exception may be allowed on a substandard lot if the structure can be moved before it is damaged by rosion. Other special exceptions are also available.

NORTH CAROLINA

Over the last 50 years over half of North Carolina's coast has experienced average erosion of 2 feet per year or greater, with 20 percent exceeding 6 feet per year. The erosion management program has the following capabilities [24]:

- o Planning
- o Regulatory
- o Land acquisition
- o Policy development

This resulted in the development of a coordinated shore-front development program that has the following responsibilities:

- o Regulates new development
- o Restricts shore erosion-control practices
- o Plans for redevelopment and relocation of damaged and threatened structures
- o Purchases land for beach access
- o Develops public education programs

The main three goals of the program include:

1) Minimize loss of life and property resulting from storms and long-term erosion.
2) Prevent encroachment of permanent structures on public beaches.
3) Reduce the public costs of inappropriately sited development.

North Carolina adopted a statewide minimum ocean setback for all new development in 1979. As a result, the minimum setback now requires all new development to be located behind the farthest landward of these four points:

1) Erosion rate setback, 30 times the annual erosion rate, measured from the vegetation line, for small structures and 60 times the erosion rate for structures with more than four units or more than 5,000 square feet total floor area.
2) The landward tow of the frontal dune.
3) The crest of the primary dune.
4) A minimum of 60 feet, 120 feet for larger structures, measured from the vegetation line.

Limited use that does not require permanent structures is allowed.

FLORIDA

In 1968 Florida initiated a comprehensive program for beach management in the Division of Beaches and Shores, Department of Natural Resources. Duties of this division include [24]:

- o Field measurements
- o Research and analysis
- o Permitting and regulation
- o Beach nourishment

To monitor beaches, the State of Florida installed a system of 3,400 concrete monuments at nominal spacings of 1,000 feet along 648 miles of sandy beach. Shoreline change is determined from repeated profile surveys from these monuments. Additionally, a separate program was initiated to establish a comprehensive data base of shoreline positions using historic information.

A main component of the Florida regulatory program is the Coastal Construction Control Line (CCCL) that establishes the state's jurisdiction in coastal construction permits. The line identifies the limits of severe fluctuations caused by a 100-year storm event. This 100-year storm event is based on extensive data collection, including field surveys, aerial photographs, numerical modeling of storm surge and beach erosion. A Department of natural Resources permit is required for any excavation or alteration seaward of this line. State law includes a 30-year erosion provision requiring single family dwellings to be set back 30 times the annual erosion rate.

In 1986 the Florida Department of Natural Resources proposed to the legislature a 10-year $472 million beach nourishment program for Florida's critically eroded beaches, which included $362 million for restoration and $110 million for renourishment. This amounts to an average of $2.6 million per mile (ranging from $1.9 million to $3.9 million per mile) to restore or renourish 140 miles of beach plus $24 million annually for maintenance on an indefinite basis.

CALIFORNIA

California's coastal erosion as well as its management are complex. The major programs include: the California Coastal Commission; California State Coastal Conservency; Department of Boating and Waterways of the Resource Agency; State Land Commission; Bureau of Land Management; Department of Parks and Recreation; State Water Resources Control Board, etc.[24].

The latest revision of the California Coastal Commission requires coastal localities to prepare their own plans for development within their jurisdiction via a Local Coastal Program. Priorities for coastal usage include the following:

- o Public access
- o Public recreation
- o Marine environments
- o Land resources, including sensitive habitats and agricultural lands
- o Development, with attention to concentration of new development, scenic resources, and development in hazard areas
- o Industrial development

The California Coastal Commission is the long-term planner for the California coast. This requires in-depth research in the following:

- o Consequences of the greenhouse effect and rising sealevels for the coast.
- o Long-term prospects for and implications of offshore energy resource development.
- o Toxic and hazardous materials handling and spill cleanup in the coastal region.
- o Long-term land use possibilities and dangers for flood and geographic hazard areas.
- o Power plant development and siting.
- o Shore erosion, especially in developed areas.
- o Scientific studies of existing coastal resources and the impact of planned development.

Because of adverse impacts associated with large coastal protective devices, the commission has favored the use of beach nourishment to reduce shoreline recession rates. In the case where structures are allowed, strict conditions and mitigative actions are part of the permit.

Each state's ability to address erosion is a direct reflection of economic pressure, social values and political will. For example, California suffers from many complex problems such as toxic and hazardous materials, etc. However, Florida created a division within its Department of Natural Resources, called the Division of Beach and Shores, that is specifically responsible for erosion matters.

<u>SRI LANKA</u>

In 1986 the country of Sri Lanka developed a <u>Master Plan for Coast Erosion Management</u> that identified erosion as the most critical problem in their Coastal Zone Management program. Objectives of the plan include in the following [16]:

- o Manage the siting of development activities in the coastal zone
  - Define setbacks
  - Designate no-build zones
- o Halt coral mining in the coastal zone
  - Identify means of rebuilding reefs in critical erosion areas
- o Minimize impact of sand mining (on erosion)
  - Conduct research to identify alternative sources of sand
  - Conduct research to define sustainable yield limits
- o Ensure that erosion control techniques are cost effective and socially and environmentally acceptable
  - Ensure that coastal works are built according to the Master Plan for Coast Erosion Management
  - Construction in areas not designated as priorities shall be permitted only if performance standards are met
  - Emergency erosion control measures shall be constructed according to Coast Conservation Department guidelines
  - Research will be conducted on coastal processes related to erosion

OMAN

In 1986 the Council for the Conservation of Environment and Water Resources was established in the country of Oman. A Coastal Zone Management Plan was developed, including:

- o Establishment of general planning policies
- o Establishment of protected areas
- o Identification of specific issues, actions, and responsibility for implementing actions

Erosion management was included with other CZM concerns.

TABLE II-3
SUMMARY OF STATE AND TERRITORY EROSION MANAGEMENT PROGRAMS

STATE TERRITORY	RECESSION RATES FROM AERIAL PHOTOS	RECESSION RATES FROM CHARTS	RECESSION RATES FROM GROUND SURVEY	EROSION SETBACK EST.*	REF. FEATURE	YRS. OF SET BACK	LOCAL ADMIN	ONE FOOT PER YR. STD.	FIXED SET BACK	FLOAT-ING SET BACK
Alabama	Y	Y	N	Y	MHW	NA	N	Y	N	
Alaska	Y	Y		N	NA	NA	NA	NA	NA	NA
American Samoa	N	N	N	N	NA	NA	NA	NA	NA	NA
California	Y	Y	Y	N	NA	NA	Y	NA	NA	NA
Connecticut	Y	Y		N	NA	NA	NA	NA	NA	NA
Delaware	Y	Y		Y4	TD	NA	Y	N	Y	N
Florida	Y	Y		Y5	NA	30	Y	N	Y	N
Georgia	Y	Y		N	NA	NA	NA	NA	NA	NA
Hawaii	N	N	N	Y	6	N	Y	N	Y	N
Indiana	Y	N	Y	N	NA	NA	NA	Y	NA	NA
Illinois	Y	Y	Y	N	NA	NA	NA	Y	NA	NA
Louisiana	Y	Y	N	N	NA	NA	NA	NA	NA	NA
Maine	N	N	Y	N7	NA	NA	NA	NA	NA	NA
Maryland	Y	Y		N	NA	NA	NA	NA	NA	NA
Massachusetts	Y	Y	N	N	NA	NA	NA	NA	NA	NA
Michigan	Y	N	N	Y	BC2	30	Y	Y	N	Y
Minnesota	Y	N	N	N	NA	NA	NA	Y	NA	NA
Mississippi	N	N	N	N	NA	NA	NA	NA	NA	NA
New Hampshire	N	N	N	N	NA	NA	NA	NA	NA	NA
New Jersey	Y	Y	Y	Y	MHW	50				
New York	Y	Y	N	Y	BC	30-40	Y	Y	Y	N
North Carolina	Y	N		Y	DC	30-60	Y	N	N	Y
North Mariana's	N	N	N	N	NA	NA	NA	NA	NA	NA
Ohio	Y	Y	N	N1	BC	30	NA	Y	Y	N
Oregon				N		NA	NA	NA	NA	NA
Pennsylvania	Y	N	Y	Y	BC	50+	Y	Y	N	Y
Puerto Rico	N	N	N	N	NA	NA	NA	NA		
Rhode Island	N	N	Y	Y	DC	30	N	N7	Y	N
South Carolina			Y	Y		40	BL		Y	N
Texas	Y	Y	Y	N	NA	NA	NA	NA	NA	NA
Virgin Islands	N	N	N	N	NA	NA	NA	NA	NA	NA
Virginia	Y	Y		N	MHW	NA	Y			
Washington				N	NA	NA	NA	NA	NA	NA
Wisconsin	Y	Y	N	N3	NA	NA	NA		N	Y

Note: 1=setbacks may be established within 2 years; 2=bluff crest or edge of active erosion; 3=some counties have setbacks; 4=has 100 foot setback regulation over new subdivisions and parcels where sufficient room exists landward of setback; 5=not all conties have coastal construction control lines established; 6=storm debris line or vegetation line; 7=2 feet per year standard. y,yes; n, no; NA, not applicable; BC, bluff crest; MHW, mean high water; TD, toe of dune; DC, dune crest, toe of frontal dune or vegatation line; BL, base line. A blank means no information was available.

* Most states have setbacks from water line but not based on an erosion hazard.

"Managing Coastal Erosion" [22]

D. MISSION STATEMENT

The mission of the successful erosion management plan should support an overall shoreline management plan and consider issues that pertain to coastal areas, including the following:

- o estimate current and future needs of the community
- o protect valuable open space from unnecessary encroachment and destruction
- o establish principles and standards designed to achieve an optimum scenario
- o identify public and private actions necessary to achieve goals
- o protect public and private investments from erosion or destruction

Hawaii is unique because its land use laws heavily interact with coastal zone management regulations to such a degree, that they appear to be inseparable. As such, a unique approach will have to be formulated for the state, tailor-made to effectively fit into the existing regulatory scheme.

The mission of an erosion management program (EMP) should be broad to address the very complex issues associated with erosion; however, it should be specific so that direction and guidance is provided. Mission guidelines, objectives and goals must provide support so that the mission is met. Objectives and goals should have distinguishable and measurable products, whereby progress, success and/or failure is measured. Goals and objectives can later be included in a coastal resource plan that will coordinate and regulate coastal zone utilization. The development, interpretation and execution of the EMP must take into account social as well as economic considerations, both with respect to execution and administration. The EMP will also provide reasonable guidance for future decisions with respect to resources and manpower.

The following mission statements were considered for the EMP:

1) "Protect, preserve and where possible enhance coastal resources from erosion effects, for the benefit of the general public."
2) "Conserve beaches and minimize erosion."

Although we clearly believe that the outcome should benefit the public, we chose mission statement 2 because it focuses on erosion, yet it allows for a broad interpretation.

E. MISSION GUIDELINES

Mission guidelines that further describe the mission statement for an EMP include the following:

- o Areas with a high storm hazard risk must have adequate planning to accommodate erosion.
- o Retain as much coastal beach as possible.
- o Retain shoreline in its natural state.
- o Permit erosion control methods that will have the least environmental impact (e.g., nourishment, seawall, etc.)
- o Adopt a thirty (30) year planning horizon for erosion cycles.
- o Disagreements and other disputes should be resolved via mitigation and dispute resolution methods.
- o Special variances and conditions should be granted where five (5) or more adjacent landowners share common problems and solutions.
- o Decisions should be made with the following order of consideration; beach conservation, public access, public recreation and marine environment.
- o Information collection and management should be an ongoing process.

F. MISSION OBJECTIVES/GOALS

Mission objectives identify the activity, group or condition that must be addressed. A variety of activities that cause erosion need to be controlled, addressed and in many cases stopped, including the following:

- o Improper seawalls
- o Improper groins
- o Hurricanes and tsunamis
- o High surf
- o Sand mining
- o Excess recreational use
- o Fresh water and/or pollution on reef
- o Excessive armoring coastlines
- o Environmentally unsustainable development

Various options are available to control erosion, including the restriction or controlled use of many of the previous activities, as well as the proper use of structures, nourishment, etc.. Additionally, it may not be reasonable to stop erosion (it may not make economic sense). This should be part of the planned response to erosion in certain situations.

Specific objectives of the EMP can be summarized as the following:

- o Prevent activities that cause erosion
- o Control existing erosion

Five-year goals recommended for the EMP include the following:

- o Information collection (e.g., erosion, boundaries, etc.).
- o Public education program.
- o Improve efficiency of regulatory process (e.g., Office of State Beaches).
- o Develop EMP policies (e.g., setback scheme, monitoring method, compensation).

Long-term goals recommended for the EMP include the following:

- o Information collection.
- o Research (e.g., sand sources).
- o Enforcement system.
- o Information management.

G. EROSION MANAGEMENT PLAN EXECUTION

Execution of the erosion management plan must consider the coordinated interaction between information, planning and administrative needs.

Information and technology is key for the successful execution of the EMP. Information collection has two phases: (1) a short term data collection and (2) long-term data maintenance phase. There are always tradeoffs between the amount of information and cost. These tradeoffs can be guided from the rhetorical question: "How much information is needed to make a good decision?" A good decision is one that adequately addresses the immediate problem and is always a relative judgement-call. It does not cover all possible cases. Technology has the same kind of trade-offs between cost and effectiveness. An off-the-shelf design is always less expensive; however, it might not provide the level of service that a custom design would provide.

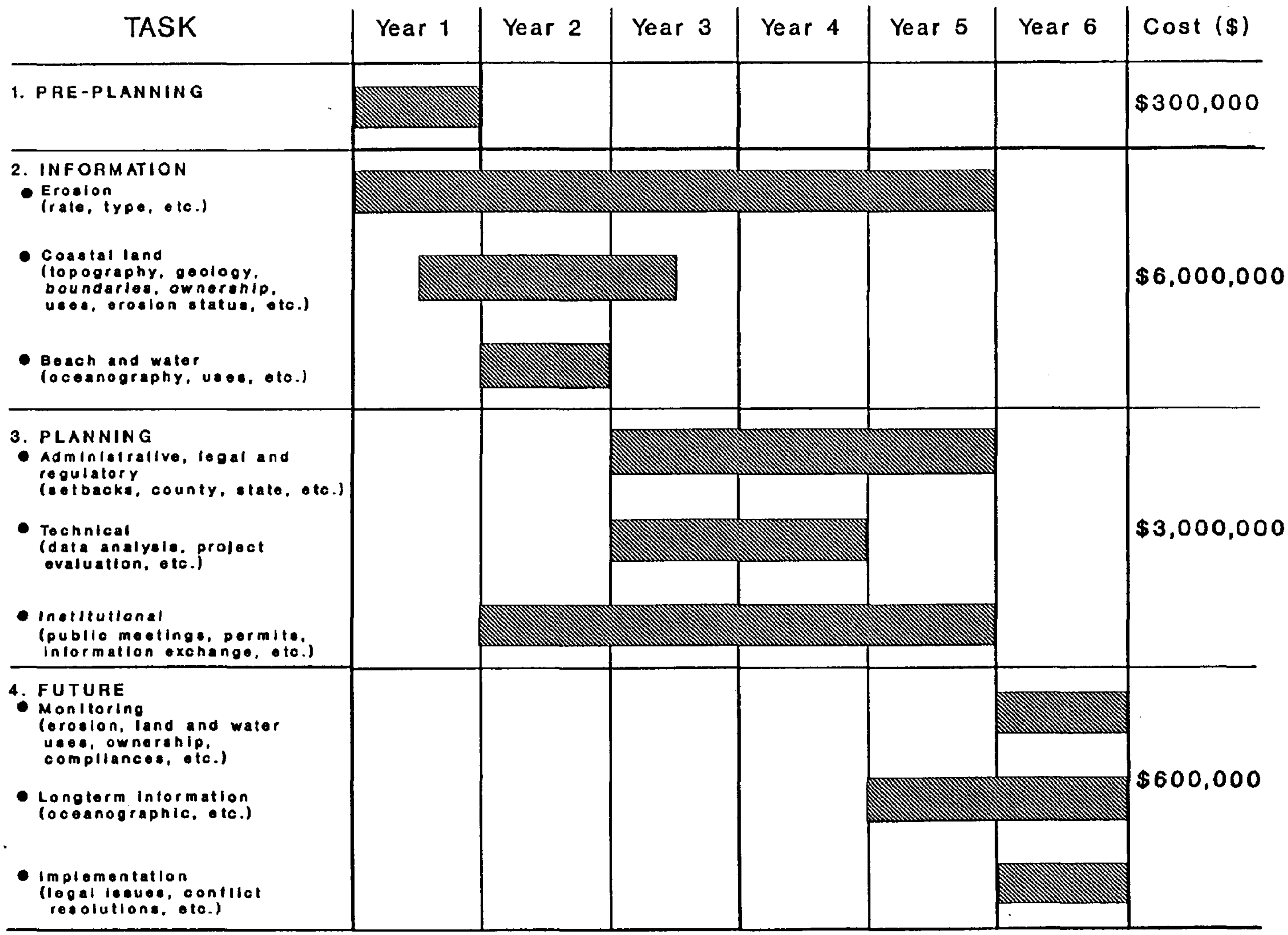
Planning considerations must address issues such as land-use, infrastructure, setbacks, improvement districts, densities and the corresponding rules and regulations that would govern these activities.

Administrative concerns are important for the successful execution of the plan. Fiscal planning needs to be part of the very first steps taken to construct an EMP. Initially costs will be high because of major data collection efforts. Later, only maintenance and operation costs will exist. Administrative concerns will be a direct reflection of fiscal limitations and controls the number of individuals employed to maintain data systems, support the processing of related permit applications, and addresses the various legal and institutional issues related with the execution of the program.

H. EROSION MANAGEMENT PLAN SCHEDULE

The goals of the EMP include the timely execution of tasks that will support the mission guidelines and objectives. Goals that should be considered in the development of the EMP are given in Figure II-1.

Figure II-1 EROSION MANAGEMENT PLAN SCHEDULE



III. EROSION MANAGEMENT PROGRAM PLANNING

A. EROSION MONITORING METHODS

Beaches are the natural boundary between land and sea, and are also the natural defense land has to resist erosive forces from waves and currents. Beaches are either calcarious or sedimentary. Calcarious beaches are typically found in tropical and subtropical climates. Sedimentary beaches are found in more temperate climates.

Geologically, beaches are one point in the cycle of formation and destruction of sedimentary rocks and land masses. Sediments eroded from mountain areas far inland are brought to the coast by rivers. Once at the beach, sediments are ground finer and finer by waves while being carried along the shore by littoral currents. When the sediments are too fine to settle in the nearshore area, they drift offshore and settle in the deep sea. Sediments deposited in this manner build up over long periods of time into thick layers and metamorphose into sedimentary rocks. Tectonic movements in the earth's crust push these sediments above the water surface to form mountain ranges and start the cycle again. Therefore, beaches are one point in the sedimentary cycle that marks geological time.

Calcarious beaches are supplied from biological activities that occur in the nearshore area. Among the various processes, photosynthesis reduces the acidity of seawater whereby coral polyps absorb dissolved calcium chloride and convert it to calcium carbonate. Millions of coral polyps living in groups form large coral reefs. The fragile portions of these reefs are broken up by wave action and are brought to the beach as a source of sediment. Gradually the particles are ground to fine sizes and drift to deeper waters. When these settle in deeper waters the slightly higher acidity dissolves the particles of calcarious origin. The dissolved material eventually reaches the shallow waters due to circulation and are converted back to calcium carbonate by the corals. Other sources of calcarious material include grazing reef fish that snap and nibble coral and coralline algae.

Beach sediments are sometimes carried into coastal lagoons by flood tides and temporarily trapped as shoals or sand bars. Other sediments are blown landward and trapped as coastal sand dunes. During heavy storms when beaches experiences large waves, part of the sand trapped in the dunes is utilized to save land behind the dunes from erosion. Due to the interaction of sediment supply, meteorological and oceanographic forces, beaches undergo continuous change all the time.

Some of these changes occur over short intervals of time (up to a year) and are termed seasonal or cyclic. However, longer term imbalances between supply of sediment and loss of sediment result in continuous erosion or accretion. This can take place over several decades or even longer until a new balance is created by natural or artificial means. In the case of small islands far from continents, the sources of beach material are limited to the sediments brought by runoff from mountain areas and calcarious sediments from coral reefs and other marine sources. In these cases, imbalances can result in serious erosion or sedimentation problems. Erosion in these cases can continue until hard strata is exposed.

Urbanization and settlement of coastal lands has added a new dimension to the instability problem. Initially, beaches were believed to be extremely stable and would take any amount of abuse. However, the construction of harbor breakwaters and other navigational structures caused modifications to the existing coastal processes that resulted in coastal erosion and sedimentation in undesirable areas. Engineering solutions that followed resulted in hardening parts of the coast with seawalls, or the disruption of longshore sand transport from groins that caused erosion in downdrift areas. It took time to realize that many of the activities in the coastal zone upset the existing and delicate beach equilibrium.

A.1 BACKGROUND

The concept of coastal zone management was developed as a means to resolve the complex problems arising from conflicting uses of limited coastal resources and to conserve coastal resources for the future. As a first step in coastal management, construction setbacks were established to control development activities in the coastal zone.

MONITORING COASTLINES

Determination of setback distances and planning for coastal developments depends on the potential hazards faced by the coastal land of interest. Hazards include erosion and flooding due to tsunamis and storm waves. In the absence of hard data, the long-term erosion hazard can only be estimated by evaluating coastal vegetation or by speaking to residents who have lived close to the beach for a long period. Comparing historical aerial photographs with recent photographs provides qualitative conclusions based on coastal behavior.

Shoreline changes that were of interest only to coastal geomorphologists now attract the interest of coastal zone planners and coastal engineers. Shoreline change information is also needed for estimating sediment movement, predicting effects of shoreline structures, and establishing setbacks for control of development activities. The types of information available, advantages and disadvantages of methods used, based on cost, accuracy, technical requirements and institutional resources available, will be discussed in the following sections.

HISTORICAL SHORELINE MAPS

National Ocean Survey (NOS) topographic sheets are among the oldest coastline maps available. These are also the most accurate maps available for comparison purposes. They were prepared usually by field surveys, later versions were compiled from aerial photographs using stereo-plotters for rectification and plotting. NOS sheets can be changed and updated using aerial photographs, which are periodically available. NOS "T" sheets are available with a scale of 1:10,000; stable points located on the maps are accurate to 1/75 inch of actual position. Therefore, the smallest field distance measurable in a map is about 7 feet to 16 feet for stable points [3]. Accuracy may be less for less unstable points such as the shoreline.

Maps prepared by the United States Geological Surveys (USGS) cover a 7.5 minute square and are plotted to a scale of 1:24,000. These maps show more land details but were prepared to comply just within the guidelines of national map accuracy standards. USGS maps are accurate to 1/50 of an inch, which amounts to errors of up to 40 feet when determining the position of a stable location on land. Any measurement from these sheets can be in error up to 40 feet.

Local surveys made for land use and development activities close to the coast may be available in developed coastal areas. These maps usually are made to large scales and provide for higher accuracy measurements. However, they may contain only short stretches of the coastline. New field measurements are necessary to calculate land loss from these maps. The resulting land loss calculated this way will be very accurate and can probably be used to check accuracy of other methods. In cases where shoreline levels are available, volumetric sand losses can be calculated using consecutive beach profiles.

AERIAL PHOTOGRAPHS

Aerial photography is an attractive alternative to time consuming field surveys for monitoring coastline change. Many states already use this method for shoreline monitoring. Aerial photographs pick-up all available ground details, whereas field surveys present only selected details. Therefore, comparing photographs offer great flexibility. Common details will be available even if photographs were made by different companies for different purposes. Preparation cost is fixed; large areas can be photographed at a relatively low unit cost. When aerial surveys are performed with properly surveyed ground marks, accurate maps can be constructed. Most of topographic sheets are prepared with stereo-plotters and stereoscopic photo pairs that are corrected for errors. However, this involves expensive instruments and expert services.

Aerial photographs used for shoreline monitoring can also give inaccurate results. The waterline position depends on many parameters. Water levels are affected by tides, winds, and waves. Mean waterlines move horizontally on a sloping beach due to water level variations. Additionally, seasonal beach variations also causes the waterline to move. The waterline responds to cyclic accretion or erosion by moving offshore or landward. A coordination of these parameters with aerial photographs make the process very expensive. Errors result when photographs taken during different phases of the cycle changes are compared and long-term erosion results are extrapolated. Furthermore, abnormal conditions, i.e., storms, can cause large temporary changes in the shoreline. Aerial photographs taken immediately after such an event should not be used for monitoring long-term trends. In areas where long-term erosion trends are small in comparison to seasonal or cyclic changes, waterlines are not a good parameter for comparison.

Coastal changes measured from aerial photographs reflect only the change in land area. However, rates of erosion, as well as impacts from protective structures, depend on the volume sand transport due to littoral processes. This lack of three dimensional information can cause substantial errors in predicting shoreline changes, particularly if the land behind the shoreline shows appreciable relief.

Distortions cause differences between aerial photographs, which arise from the methods used and limitations of the instruments. The scale of an aerial photograph depends on the height of the camera. Atmospheric disturbances make it impossible for a airplane to always fly at the same height relative to the ground or to fly on a perfect straight line. Photographs taken successively during the same flight may have different scales due to variations in the flight altitude. Edges of the photographs may show discontinuities from the vertical and horizontal movements of the airplane. The scale of each photograph may need correcting for removal of distortion.

When camera axis is not exactly vertical, the center point of the photograph does not coincide with the point vertically below the camera. This causes a distortion in the photograph, referred to as a tilt error. In general camera tilt is approximately one degree but under difficult conditions it can be as large as three degrees. In comparison studies, this error can be corrected by measuring distances between selected control points on maps and photographs.

Lens distortions introduce errors that increase as the radial distance from the photocenter increases. However, modern mapping cameras have high quality lenses that minimize lens distortion.

Ground relief is another factor that introduces errors into measurements made from aerial photographs. High relief introduces a scale variation in the photograph from point-to-point as well as a distortion in the main direction of the land slope. As a result, special care must be taken when points on photographs are selected for comparison with corresponding points on a map. The objects selected should be at the same level for accurate results. However, in most coastal areas ground relief is very low and the error due to this is small.

FEATURE TO BE MONITORED

For purposes of monitoring long-term trends in shoreline behavior, it is essential to select a feature that can easily be identified on aerial photographs or maps. The type of feature should also depend on the local topography and cyclic or seasonal behavior of the beach. Several different features have been used in earlier monitoring projects. These are the vegetation line [12], the high waterline [11] and the beach toe.

The vegetation line is the most seaward boundary referenced for regular land-use. Beyond this point the berm and the beach extend to the waterline. In most cases the berm is a temporary feature that can accommodate temporary vegetation, which may be less than a season old. In selecting a vegetation line the plants should be older than one year. The vegetation line shows up fairly well in aerial photographs, but is not generally marked as a detail in ordinary land maps. In general, one of the disadvantages is that, vegetation takes time to stabilize on accreting areas. Since identifying the line on photographs is subjective, field checks may be necessary in ambiguous cases.

In some projects the high waterline has been used as the monitoring feature [11]. On a sandy beach the high waterline appears as the boundary between two different shades of gray. The line is easily discernible in aerial photographs. Many researchers argue that this is a good feature to monitor over long time periods. However, the high waterline varies with the tides, waves, and winds. The high tide line itself shows a considerable variation between spring and neap tides. Waves produce a water level elevation at the beach called wave set-up. This can be as high as ten percent of the wave height and hence can be considerable in areas subjected to high swells such as the north shore of Oahu. On-shore winds also pile-up water at the coast from wind stress at the water surface. This contribution is generally small compared to other phenomena.

On a sloping beach the waterline moves a considerable distance horizontally when water levels change. For example, on a beach with a slope of one in ten (1:10) the high waterline will move ten feet due to a rise in water level of one foot. Because of this beach slope amplification and the difficulty establishing actual water levels above datum at the survey time (aerial or otherwise) this method is not suitable when the rate of shoreline change are low or moderate. The method cannot be used at all in areas devoid of sandy beaches, as is usually the case on some eroding coastlines. Because of these reasons, the high waterline is not a suitable monitoring features for Hawaii shorelines.

Beach toe has also been suggested as a monitoring feature. It is the point where the reef flat intersects the beach slope.
In general, this line is in the surf zone; during high surf conditions it is difficult to identify because of suspended sand and breaking waves. The position of the beach toe depends on the amount of sand available at the beach; therefore, it can be used to show large cyclic or seasonal variations. However, this can induce relatively large errors in predictions of long-term trends of shoreline behavior.

A.2. MONITORING METHODS

Even though several methods are available for beach monitoring, not all methods are suitable. Selection must be made after considering all relevant factors. Some of the important factors to be considered are:

- Availability of previous data.
- Resources available for field and office for implementation.
- Accuracy needed.
- Type of results expected.

- o Nature of the coastal area.
- o Land use.

Any method will require repetitive surveys at regular intervals, depending on the rate of erosion. Surveys, whether aerial or field, should be planned for the same time of year to minimize errors due to seasonal changes. Determining the most suitable boundary to monitor, e.g., high waterline, vegetation line, etc., is also an important factor in long-term monitoring.

BEACH PROFILE MEASUREMENTS

Beach profiles are transects perpendicular to the shoreline that show ground level details. Usually they are evenly spaced, level measurements conducted regularly along the beach profiles. An initial survey to find the position and direction of the lines, and to establish level datum must be carried out. Repetitive surveys can then be performed with relative ease.

Data obtained is very accurate and data analysis gives the increase or decrease of area between the profile and the selected datum. Volumes of beach material lost can be calculated using numerical integration between successive beach profiles, assuming a linear change in the shore profile between sections. However, this is not strictly correct because some of the actual profiles will deviate from those calculated. This introduces an error in the volume calculations.

Movement of the selected boundary will be known accurately only at the profile locations. Linear interpolations will be used to calculate changes in between profile locations; this too can introduce error. However, profiles are generally selected with due consideration of coastal behavior, errors can be kept small. Another disadvantage is the necessity of skilled surveyors to perform field work resulting in increased cost. However, simple computer programs can be written to calculate losses once data is available.

POINT MEASUREMENTS

Point measurements are made from known points to a selected shore boundary at regular intervals of time. The points should be selected so that linear approximations are realistic between points.

Two methods are used in point measurements. The first method is similar to the profile method; however, only a horizontal distance is measured from a known point to the boundary. These fixed points have to be documented for repeated use. In areas where public utilities such as highways run close to the beach, monuments can be established easily on or by the side of the road. No land levels are measured; therefore, the monitoring technique is simple and does not need highly skilled personnel. The data obtained is one dimensional and the method suffers from all other disadvantages of the surveys.

The second method, referred to as transect analysis, makes use of historical aerial photographs where available. In this method rectified photographs are obtained and scales of the photographs are determined by identifying stable points such as road intersections or building corners on the ground and in the photograph and then correlating distances. Ground relief errors are minimized by selecting stable points at the level of coastal land. Suitable transects are decided by using conspicuous marks close to the beach that are identifiable on the photographs. Next, the boundary line to be monitored is identified in the photograph with as much accuracy as possible. Distance is measured from the fixed points to this boundary. Land loss information is extracted by comparing this distance in successive sets of photographs. Calculation can be performed using mechanical or electronic digitizing methods.

This method has all the shortcomings of field methods discussed earlier, and contains additional errors due to photographic distortion and measurement. The photographic errors can be minimized if the area of measurement falls near the epicenter of the photograph and by using rectified photographs. However, measurement errors depend on the scale of photographs used and can be as much as 15 feet on a 1:10,000 scale. Additional distortions can result in a potential error of up to 30 feet. The usefulness of the method for small beach changes is questionable. Another disadvantage is that transect locations depend on identifiable marks, the coast between these points may not be linear.

Costs incurred are low because the field work only consists of making the proper aerial surveys. However, results obtained may be below the expected accuracy. Transect analysis has been made in selected areas of Oahu, using rectified aerial photographs from 1949 to 1988. Both mechanical and electronic methods were used in performing measurements.

ORTHOGONAL GRID MAPPING SYSTEM

In this method the aerial photographs are compared with topographic sheets. A base map at 1:5,000 scale is obtained; the ocean side edge of the paper is used as a base line [11]. Rectified aerial photographs are then enlarged to the same scale as the map by projecting them directly on to the map with the shoreline parallel to base line. If the photographs are not rectified then a correction is applied by comparing object size and image size on the photograph. Then a rectilinear grid of 100 meters by 100 meters is projected on the map using the long side of the map as one axis. Next, the shoreline is digitized at points where the grid lines cut the shoreline approximately perpendicularly. The digitization is made relative to the base line established earlier.

Orthogonal grid mapping systems produce best results on long straight shorelines where the grids can be oriented perpendicular to the shoreline at the photo projection stage. This in effect amounts to a point measurement system.

Matching the enlarged projection of the photograph on to the map is subject to errors, which can arise from the quality the of photograph and human factors. This error is estimated to be as large as 10 meters. Assuming an accuracy of 1\100 inches for measurements from the photograph, this can cause a potential error of 1.25 meters at each point. This amounts to a potential error of 2.5 meters on 1:5,000 scale. Errors due to the quality of the photograph add to the above mentioned errors. The maximum potential error is about 12.5 meters in addition to map errors and photo errors.

The cost of this type of monitoring is relatively low because no expensive equipment or highly skilled personnel are needed. However, the accuracy is very low and is not suited for areas with low to moderate land loss rates. This type of monitoring has not yet been performed in Hawaii. However, basic data are available from existing topographic sheets and aerial photographs.

The shoreline shape may not be suitable for this type of monitoring due to sharp land features and a relatively rugged coastline with small pocket beaches, which may cut the grid lines perpendicularly at only a limited area in each photograph.

SATELLITE IMAGERY

Satellite imagery is typically used for land use planning and other activities where the land parcels are large. Presently, the resolution of data is limited by the pixel size, which is approximately 80 X 80 meters for Landsat Imagery. This resolution is too low for monitoring shoreline changes that may amount to a few meters per year even in heavily eroding areas. However, this may be used over long time periods; future sensors may have higher resolution. Computer methods are available that use original data before it is converted to photographs. At present resolution is too low for shoreline monitoring.

A major portion of the expense for this method will go to analysis of data, since data is taken continuously at regular intervals by satellites already in orbit. Higher resolution information will be possible in future; this method has lots of potential.

ZOOM TRANSFER SCOPE

A Zoom Transfer Scope is used for revising maps from aerial photographs. It provides a continuous differential change in magnification from 1 to 14 times between each eyepiece of a binocular viewing system. Therefore, the photograph scale can be considerably different from the map under comparison. Anamorphic lenses incorporated into the viewing optics enable one to change the scale in one direction, thereby permitting corrections for tilt and relief displacement as well as other geometric anomalies between the photo image and the map image. This method of shoreline monitoring is tedious and time consuming. Equipment is relatively expensive and trained personnel are necessary; transferring data to maps and calculating changes in the shoreline are separate subsequent activities. This method is useful for special projects; equipment cannot be used for other purposes.

STEREO PLOTTING METHODS

Presently most map revisions are performed with stereoscopic pairs of aerial photographs and stereo-plotters. These machines correct for distortion due to scale, tilt, etc., and plot results that are relatively accurate. However, these machines are expensive and skilled personnel are needed to provide quality results. Resource requirements may not be justifiable for the purposes of shoreline monitoring.

COMPUTER ASSISTED DIGITIZING METHODS

Recently, a new, semi-automated shoreline mapping technique (METRIC MAPPING) [7] has been developed that uses computer techniques together with aerial photographic analysis, which are made by aerial mapping cameras to ensure high image quality. Base maps used in this case are topographic sheets made by National Ocean Survey (NOS "T") and are available for many areas dating back to several decades. Stable control points are selected on NOS "T" sheets and are digitized to convert map coordinates into the state plane coordinate system. Aerial photographs are then selected as stereo pairs using a magnifying stereo viewer, the shoreline is drawn on the aerial photograph as a thin line. Control points such as road intersections or building corners that appear on the map as well as the photograph are identified. The map coordinates of these points are converted to the state coordinate system using the primary point coordinate relationship established earlier. A secondary set of corresponding points on the map and photograph are used to correct scale and other distortions in the photographs. Discontinuities at adjacent photograph boundaries are then smoothed using a computer. Finally, maps of the new shoreline are plotted. Comparisons may be made using final corrected coordinates of the shoreline before plotting; thereby, avoiding direct measurements off maps and associated errors. Shoreline change accuracy obtained depends on map accuracy, as well as shoreline selection and control point accuracy.

A major part of the work is done by a computer; the method is relatively inexpensive. Equipment needed is generally available, and the need for skilled personnel is low. Results produced are relatively free from distortion. However, map accuracies and other errors can result in errors up to 26 feet, if 1:10,000 maps are used and a 1/64 inch digitizing accuracy is available. Additionally, errors of up to 13 feet are possible when 1:5,000 scale aerial photographs are digitized to the same accuracy as the maps. Accuracy of the NOS sheet is about 7 to 16 feet, which causes uncertainty in the results.

OTHER LOCATIONS

In many other states shoreline monitoring is carried out using combinations of aerial photographs and, field surveys [10]. Digitizing aerial photographs is performed in Delaware, Massachusetts and New Jersey. Aerial photography is performed in California, where the coast is rugged and seasonal variations are much larger than long-term trends. Aerial photographs are also used in Michigan, Ohio, Pennsylvania, Puerto Rico and Wisconsin. Indiana, Maine, New York, Rhode Island, North Carolina, South Carolina, and Texas use aerial photographic studies supplemented with topographic or other field surveys. Georgia makes use of historical maps.

Example data collection programs from several states include the following [24]:

- o Pennsylvania and Indiana update recession data with ground surveys every two years.
- o North Carolina updates with aerial photographs every 5 years.
- o Michigan and texas update every 10 years.
- o Florida, each county updates every 10-12 years.

A.2.a. RECOMMENDATION/BEST METHOD

Several factors should be considered when selecting a method for erosion monitoring. The main issue is the amount of information necessary to make appropriate management decisions. Any method that utilizes available historic data will be helpful in making immediate management decisions. Therefore, data can be in the form of maps or aerial photographs. Results can be used to address immediate management needs. Information needed for future and long-term planning and management may require specific data collection and processing methods.

Important criteria to be considered, particularly for long-term monitoring programs, is how the information obtained from the monitoring program will be used for coastal management and development projects. All methods discussed above except beach profile measurements and stereo-mapping techniques will result in only rates of land area change due to the changes in the shoreline. This information may be adequate for management issues such as setback determinations and related public use of beaches. However, results will not indicate volume losses of beach material, which is more closely related to predictions of future coastal behavior. The insensitivity of these methods to hazards related to land levels such as flooding and subsidence is another serious disadvantage of the other methods. Volume changes of beach material and the susceptibility of coastal land to inundation due to severe storms or flooding are important from social as well as coastal engineering points of view. Data on long-term volume losses of beach materials are extremely useful in designing coastal stabilization, sand nourishment requirements and for evaluating impacts of coastal projects on adjacent coastal and offshore areas.

Large-scale shoreline maps and historical aerial photographs used for determining erosion rates always lead to the questions regarding confidence in results. As discussed earlier, most map and photograph digitizing methods involve errors. Uncertainty in maps and photographs casts a shadow on the accuracy of results.

This is particularly true in highly developed areas where the rates of erosion are low but the consequences of erosion are economically significant. Land loss near valuable public infrastructure and facilities, e.g., main roads, is a good example. In such cases information obtained from remote operations, such as aerial photography, may not be accurate enough. Point measurements from monuments established close to the beach will give more useful information at a higher cost.

Aerial methods are cost effective for preparing surveys of long beach stretches. However, compiling accurate maps for monitoring purposes involves stereo-plotting equipment and highly skilled technical personnel. The absence of clearly distinguishable ground features in early aerial photographs, particularly in less developed areas, is a serious drawback in their use for comparison studies. Accuracy can be improved without significantly increasing cost by clearly establishing distinguishable marks on the ground at predetermined locations, and including a few of these marks in each photograph. Large white circular patches can be established as marks when located on easily identifiable coastal roads; thereafter their coordinates can be calculated with respect to the state coordinate system during field observations. Establishing and identifying these features in aerial photographs, maps and on the ground is a necessary step for correcting distortion in photographs. Ideally these marks should be at the same level as the vegetation line. This may not be critical in coastal areas of low land relief.

Because Hawaii consists of a series of islands, erosion problems are critical even over a relatively short length of coastline. In critical areas where management decisions can lead to economic or legal issues, accurate data on beach recession is necessary. In other areas where erosion and related socio/economic issues are not critical, accuracy from results obtained using digitization techniques and aerial photographs may be suitable.

The extent and rates of erosion experienced must be weighed against the cost of monitoring methods. In areas where decisions must be made immediately, digitizing methods supplemented with profile measurements are recommended. In areas that are critical, simultaneous photographic and field profiling methods are recommended. Information will be used to select the best method for subsequent monitoring surveys. In areas where coastal development activities are relatively low, monitoring methods that use digitizing techniques are recommended.

Monitoring surveys must be made at regular time intervals with repetitions once in three to five years. As mentioned earlier, the best monitoring feature is the vegetation line. The finished photograph scale should not be smaller than 1:20000. With a larger scale, identifying the vegetation line and other features will be easier; however, photographic distortion at overlapping areas may be high. The cost at larger scales will be correspondingly higher. In general photographs at a scale of 1:10000 are suitable for monitoring purposes. Aerial surveys should be carried out during seasons with low wave activity, preferably in summer. Field measurements should be performed simultaneously so results can be compared.

TABLE III-1

COMPARISON OF SHORELINE MONITORING METHODS

METHOD	COST	TIME	ACCURACY	ASSESSMENT OF SUITABILITY for Hawaii
1. Profile Measurements	Medium	Medium	0.5' Horizontal 0.05' Vertical	Good for Highly Developed Areas
2. Point Measurements	Medium	Medium	0-0.5' Horizontal No Vertical Data	Good for Medium Developed Areas
3. Orthogonal Grid Mapping	Low	Low	30-45' Horizontal No Vertical Data	Poor
4. Satellite Imagery	Low	Low	80-120' Horizontal No Vertical Data	Poor
5. Zoom Transfer Scope	Medium	Medium	< 20' Horizontal No Vertical Data	Fair
6. Sterio Plotting	High	High	0-.5' Horizontal	Fair
7. Computer Assisted Digitizing Methods	Medium	Medium	7-26' Horizontal at 1:10,000	Fair

A.3. IMPLEMENTATION SCHEME

The following procedure is recommended for implementation of the monitoring program:

1) Collect all available data including aerial photographs, maps of coastal areas, local surveys maps, etc.
2) Evaluate suitability of the data for different types of analysis.
3) Use aerial photographs and computer aided digitizing methods for calculating the past recession rates using vegetation line as the monitoring feature.
4) Identify areas undergoing critical erosion by using the extent of economic loss as the criteria. These areas must be identified in coordination with State and County agencies, which will eventually engage the problem.
5) Establish marks identifiable on the ground from aerial photographs, as-near-as possible to the shoreline level. These marks will be used as secondary control points. Mark these points on existing maps, or calculate their central coordinates using field measurements. Circular white marks on main road intersections or other black background are easily identifiable on photographs. These marks may have to be renewed prior to each flight.
6) In order to establish the accuracy of shoreline monitoring by digitization methods, simultaneous aerial and field surveys must be performed. Comparison of field survey results with those of digitized aerial photographs will show the accuracy obtainable as well as the relative costs of the two methods. These results can be used to decide on the best method for future monitoring. A time lag of up to a month between the aerial and field surveys may be acceptable if the two cannot be carried out simultaneously.

Results from data analysis should be presented in final form, including raw data, to the public and all agencies involved with shoreline control activities. The State's GIS system is suitable for storage of this data, which should be made available for planners, engineers, and other professionals involved in coastal development and management activities.

B. GUIDELINES AND CRITERIA FOR RESPONDING TO EROSION HAZARDS

Coastal erosion is a natural land formation and modification process that is nature's way of seeking an equilibrium at the land/sea interface. Sometimes erosion is undesirable due to the risk of loosing coastal protective structures or socio/economically important recreational and commercial facilities. Previously, engineering solutions were implemented without evaluating impacts on the environment. This resulted in degrading the coastal environment and, in some instances, caused problems to adjacent areas. Since then, an awareness has developed whereby engineering techniques combined with an overall management approach is desirable for hazard management and conservation of coastal resources.

Two basic options are available for responding to coastal hazards. One is to apply properly designed engineering solutions that are directed only at the erosion problem. The other is to develop a comprehensive management program to conserve coastal resources and control coastal hazards. It is sometimes necessary to utilize a combination of these approaches to optimize solutions.

Engineering solutions include:

- o Construct properly designed shore protection structures like seawalls, revetments, groins and detached breakwaters.
- o Nourish eroding beaches with sand from some other source at regular intervals in order to restore losses.
- o Combine sand replenishment with structures designed for retaining the sand for an extended period.

Management solutions include:

- o Relocate endangered structures (roads etc).
- o Establish setback for new development.
- o Relocate people away from high risk areas.
- o Inform the public regarding the degree of risk in hazardous areas.

Beach sand sources can also be improved by creating conditions conducive to coral growth. Submerged artificial reefs could act as nuclei for developing this type of beach material source.

B.1. ENGINEERING CONSIDERATIONS

Three types of engineering structures are frequently used in controlling coastal erosion. Each structure affects the coast and coastal processes in different ways. Seawalls and revetments are constructed approximately parallel to the coast along the edge of an eroding scarp. They prevent erosion by retaining the loose material behind the structure, which is designed to withstand wave forces as well as ground water forces. This type of structure will have only a limited effect on coastal processes because they do not cross the waterline under ordinary conditions. However, they cause hardening of the shoreline and increase wave reflection, which may have a detrimental effect on accretion processes. Groins, on the other hand, are used in erosion control when strong littoral currents are the main cause of erosion. Groins are constructed perpendicular to the coast as a barrier to the littoral currents; they trap littoral material moving along the beach. They also push the longshore currents seaward reducing their erosive potential. Therefore, groins change littoral processes in a limited area and interrupt longshore transport of sand. This causes erosion to downdrift beaches.

Detached breakwaters are constructed parallel to the coast at some distance seaward from the shoreline. They absorb a portion of the incident wave energy and deform nearshore wave patterns drastically. Changes in nearshore wave patterns modify existing littoral processes; with proper design they can be used to control erosion. However, local coastal process modifications will ease erosion problems in one area while aggravating problems in adjacent areas. In all of these cases structures either harden the coast or create local modifications to the sand movement that mitigates erosion.

Land erosion is basically an imbalance between sources and losses of sand (sinks). This concept has been ignored in all three solutions mentioned above. Structures only alter the pattern of beach loss.

Structures like seawalls and groins create problems of beach access as well as recreational use of the beach. The scenic value and continuity of the shore will be adversely effected by visual barriers caused from groins. Depletion of beach resources in adjacent areas may lead to difficult legal problems where assessing the amount of loss due to the construction is almost impossible.

Nourishment of eroding beaches with appropriate material that will counteract an imbalance between sources and losses is an accepted solution to coastal erosion. This has the advantage of creating or maintaining recreational areas. Environmental impacts could be minimized if the rate of replenishment could be matched to the rate of beach material net loss. However, this is not possible because of implementation problems. At best, nourishment schemes are typically carried out at regular intervals where the amount of material supplied at each execution is sufficient to last several years. This temporary excess of material can end up in undesired locations and sometimes can smother coral reefs or cause sedimentation in nearby waterways or lagoons. Extensive studies have to be made when selecting the proper type of material and the acceptable amount that can be supplied at any given time. It may be advantageous under some circumstances to combine sand nourishment schemes with structures designed to retain the sand for a longer period. Additionally, encouraging natural growth of coral by creating environments conducive for growth of suitable coral species can result in an increase in available natural sources.

B.2. SOCIO/ECONOMIC CONSIDERATIONS

Coastal erosion and beach preservation measures must also consider the various social and economic issues that arise. To address these issues, an inventory of the following items should be included in the comprehensive database:

- o Existence, location and current levels of usage of public access to the shoreline
- o Existence, location and current levels of usage of public access along the shoreline
- o Existence, location and current levels of usage of ancient Hawaiian trail systems along or to the shoreline area
- o Public recreational uses of the shoreline and levels of usage

These issues are not confined to coastal erosion per se, and must be addressed in a comprehensive shoreline management plan. The comprehensive plan should consider the following:

- o Anticipated future levels of usage with regard to public access and public recreational use.
- o Adequacy of current access and recreational availability with respect to meeting anticipated future needs.
- o Preservation of verifiable ancient Hawaiian trail systems and kohaniki rights.
- o Optimum public utilization scenario to address anticipated levels of usage.
- o Necessity of implementing beach nourishment or shore protection measures to achieve optimum scenario.

Legal issues often arise with respect to government's ability to regulate uses of private shorefront property. The primary issue typically centers on whether the regulation constitutes an unconstitutional taking or results in an inverse condemnation action. In general, such statues or regulations have been upheld where courts have been able to find that the statute or regulation substantially advances a legitimate state interest, and does not deny the landowner of an economically viable use of property.

The development of a comprehensive shoreline plan should bolster the legitimacy of the regulatory action if the plan is formulated to contain clear policy objectives and supporting justifications.

In addition, to address these legal issues, the guidelines, rules and regulations for implementing the plan should, at a minimum, be formulated to provide the following:

- o Give special exception to landowners in situations where there will be damage to existing residences or like structures due to coastal erosion.
- o Consider the impact of loss of private property from coastal erosion processes with respect to lot size and configuration, and ability to utilize lot for permissible purposes.
- o Provide an administrative appeal procedure.

Even though coastal erosion affects all aspects of the coastal zone, erosion management is only a part of coastal zone management. A management plan for the coastal zone should address conservation of all resources and should have provision to control all activities that effect this resource. Hazards to life and property arising from natural causes such as tsunamis, storm flooding or erosion can only be minimized by controlling development and use activities.

The public should be informed of potential hazards that exist in coastal areas from natural events such as tsunamis and storm flooding, as well as the probable frequency of such events. The intensity and the frequency of hazards will depend on factors like exposure of the coast, offshore bathymetry, backshore elevations and relief as well as the degree of development. Setback distances should be established by evaluating potential hazard intensities and frequencies. It may even be necessary to relocate residential areas from high risk to low risk areas. Engineering structures may be the only acceptable solution in certain areas where existing public infrastructure is in close proximity to the beach. Relocation may be acceptable when public structures are threatened by erosion.

The socio/economic issues arising from erosion are somewhat similar to those that are important in considering development activities within the SMA. These considerations include the following:

- o Loss of public beach access.
- o Loss of recreational facilities and wild life areas.
- o Hazards to beach users.
- o Loss of public facilities.
- o Damage to the coastal environment.
- o Damage to coastal ecosystems.
- o Loss of scenic resources and viewsheds.

Consequences from the first four will show an immediate social impact because the public will be directly effected. Loss of public facilities such as parking areas, changing rooms etc. does not involve rights of private individuals. It enables the use of relatively straightforward mitigative measures where no legal or other confrontation arises.

However, when recreational beaches are backed by valuable private land, the land owners will attempt to protect their properties from erosion by constructing protective structures such as seawalls. This type of structure will effect public access to the beach and may even result in loss of recreational beach area in the vicinity of the structure.

The adequacy and suitability of a coastal structure are two separate considerations. A seawall may be structurally adequate to protect the land behind it from erosion and if properly designed will not damage the beach in front of it. However, erosion is not a process that effects isolated points on the beach. In general, a considerable length of the coast undergoes erosion at a given time. The erosion problem can be contained effectively only when a solution for the entire beach stretch is formulated. This provides a suitable solution for erosion problems. Hardening a small portion of an eroding beach may increase the rate of erosion at adjacent coastal areas and cause additional problems. The suitability of a protective structure for this situation must be evaluated independently.

Failure of an inadequately constructed structure may damage the property it was meant to protect, irreparably damage the beach; may even create hazardous conditions for beach users. Additionally, the scenic and recreational value of the beach will be reduced from scattered rocks and other debris.

Structures and erosion may cause the loss of recreational water uses such as surfing and other wave dependant sports. Changes in wave behavior from bathymetric alterations caused by erosion, or as a hydraulic response from the protecting structure, can result in an environment not suitable for wave sports.

Damage to coastal ecosystems, loss of scenic resources and viewsheds, as well as damage to the coastal environment will affect the economic importance of a coastal area. This is particularly true in the State of Hawaii where the tourist industry is oriented to coastal and undersea recreational activities. These factors show that coastal erosion and construction of non-conforming protective structures will lead to adverse socio/economic impacts. However, when valuable property bordering the beach is eroding the land owner will do his best to protect it. Imposing conditions on these protective efforts may lead to legal problems.

"Takings" issues involve a conflict between public interest in stopping the degradation of natural resources versus an owner's asserted right to use his property as he wishes. Claims regarding specific limitations or constraints imposed on private uses of property that are so restrictive they constitute the equivalent of constitutionally prohibited "takings" of private property for a public purpose without compensation will present enforcement problems.

When narrow strips of private land bordering the coast are backed by important public infrastructure such as roadways, the erosion hazard faced by the private land should be considered as a potential future threat to the public property. In such cases the private land can be considered a buffer and adequate protection of land should be encouraged in the face of future social expenditure. This can be achieved by establishing a group of qualified personnel, e.g., in a state agency, who can provide guidance, data requirements and expertise during construction.

B.2.a. INFORMATION NEEDED

Decision making for any public resource is always difficult; however, coastal erosion related resource issues are further complicated by land ownership, existing land use, proximity of public facilities to the coast, and other socio/economic factors. A brief analysis of the most critical information needed for decision making is given in the following section.

The types of information needed for decision making can be divided into two categories: environmental and socio/economic. The environmental information including, exposure of site to tsunami and storm flooding hazards, meteorological and oceanographic data, morphologic and geologic data, topographic data, value of marine habitat, and importance of nearshore ecosystems. Socio/economic information needed includes land and water use in the coastal zone, land ownership, value of land and public infrastructure immediately hinterland, recreational value of beach and nearshore water, public access to beaches, scenic value of coast and type of development pressure on the area such as residential, commercial or recreational.

Impact from storm surge, tsunamis and high swells on coastal areas will vary depending on the exposure of the coast to such phenomena, as well as nearshore seabed bathymetry, beach characteristics and backshore relief. Tsunami flooding hazard has already been studied and information on the intensity is available for many areas. Available data must be incorporated into maps; residents of high risk areas need to be informed of the hazard risk. High density residential development in areas susceptible to flooding increases potential damage from flooding because the water flow will be restricted by buildings and other structures. Higher water flow speeds, arising particularly during the recession of flood water, can result in extensive damage due to scour. Construction should be controlled to avoid these situations.

Material eroded from the beach during a heavy storm is temporarily deposited offshore. This deposition reduces the destructive force of the waves and decreases the rate of erosion. Sand is then transported back to the beach after the storm passes. If the nearshore area shows an abrupt increase in depth or the presence of deep channels leading offshore, the sand removed by storm waves will be permanently lost. Damage from the storm in this area will be more severe and permanent. Therefore, coasts fronted by deep channels or steep bathymetry must be identified and treated as high risk areas.

Oceanographic conditions that cause erosion hazards are high water levels and large waves. Currents also play an important role, but are generally weak except close to lagoon entrances and river outlets. Water level data are well documented from tide measurements and wave data for Hawaii are available from measurements and ship observations. Data can be found in tabular form giving wave heights, periods and wave directions as percentages. This data needs to be analyzed to obtain wave climate information for areas of different exposure. Wave heights and directions are important parameters in evaluating risk because they cause erosion from longshore transport. Erosion rates depend on the geologic formation of land and the coastal geomorphology of the area. Areas with extensive dunes can survive severe storms by loosing part of the sand and building up again after the storm is over. If dune protection is absent and the backshore is low lying, the area will be at high risk from storm waves breaching through. When the coast is composed of hard geologic strata, erosion is slow and in general the backshore is steep. The risk of erosion or flooding in this situation is low.

Some nearshore environments provide unique marine habitats and delicate ecological systems. These areas are sensitive to any change in nutrients, circulation, influx of sediments and pollutants as well as physical disturbances from recreational activity. These areas should not be disturbed; development activities in adjacent areas that may cause erosion in these unique habitats should be closely controlled.

Accurate demarcation of the certified shoreline is very important for controlling of development activities. This line acts as the boundary between the conservation district and the Special Management Areas (SMA). Engineering structures designed to prevent erosion are constructed at this boundary. This line is loosely defined as the vegetation line and leads to different interpretations by officials and land owners. Applications for Shoreline Setback Variances (SSV) cannot be processed efficiently when the location of the certified shoreline is in doubt. Attempting to determine the line after the application is forwarded leads to confusions and unnecessary delay. This line ideally should be defined from monuments on land and updated periodically, as in the case of other district boundaries.

Socio/economic information that needs to be considered will depend on the land, beach, and water uses in the coastal zone. Land and water use in the area adjacent to the SMA zone is important for decision making. Land use can be residential, agricultural, commercial, recreational etc., and may include public infrastructure and facilities. Water uses can be of recreational, industrial or of aquacultural importance. Land ownership may be public or private. In the case of public lands, making a decision on erosion management may be relatively straightforward. But in cases of privately owned or privately leased lands, the value of land and hardship to the owner makes matters much more complicated.

When public facilities such as main highways are separated from the coast by a narrow strip of privately owned land, any structure constructed for the purpose of protecting the privately owned land from erosion may have an effect on the long-term safety of the road. In such cases permitting land owners to construct individual seawalls to protect their property at their convenience may not be in the best interest of the public. If private land is not protected and erosion continues, the social cost of relocating the road at a later date may be very high. In such cases serious consideration should be given to assisting the land owners in designing an overall protective scheme. The design effort could be considered as an investment that would reduce large expenditures later.

Some of the information on land-use and oceanographic data discussed above may already be available, and needs only to be compiled in a suitable way for use in erosion management. Data collection programs should be designed where additional information is needed. The types of data necessary for responding to hazards at any location will depend on differences in the environment. The degree of exposure to severe oceanographic and meteorologic conditions should be the primary consideration. Intensity of erosion and the subsequent damage should be related to the level of development and the geologic, bathymetric, and morphologic conditions of the coast. Hazards due to flooding will be dependant on development density, character of backshore, and the topography of the area. Similarly, for economic and recreational considerations, the location will be a major criteria. A set of questions should be developed for determining data necessary for responding to hazards of erosion and flooding, including the following those found in Table III-2:

TABLE III-2

EXAMPLE QUESTIONS TO DETERMINE NECESSARY DATA FOR RESPONDING TO EROSION AND FLOODING

1) What is the level of inundation expected for a 100 year tsunami?
2) What is the water level and wave climate expected for the 100 year storm?
3) What is the highest water level expected within the next 100 years?
4) What is the heaviest runoff expected?
5) What is the worst wave /swell climate expected in the next 100 years?
6) What is the geological formation of the coast? (ease of eroding)
7) What is the character of the backshore? (dunes/rising/low lying etc.)
8) What is the major purpose of land utilization?
9) What is the major water use if any within the SMA?
10) What is the pattern of land ownership?
11) Is the beach accessible conveniently to the public?
12) Is the area used by the public for recreation?
13) Are there any public facilities close to the coastline?
14) Are there any commercial uses of the coast? (harbors/marinas etc.)
15) Is the area heavily built-up with residential units?

B.3. RESPONSE TO EROSION HAZARD

In general, waves approach the coastline at an angle, which results in a current parallel to the beach. This current is weak but since sediments are in suspension in the breaker zone it is capable of moving large amounts along the beach. This is called the littoral drift and is responsible for distributing the sand available from sources to all parts of the beach. When the source capacity is lower than the littoral drift, beaches undergo erosion. This type of erosion can continue for decades or even longer until a new equilibrium is reached. In most areas the wave climate shows a cyclic pattern over a period of one year. Because of this, the onshore/offshore movement of sand and the littoral drift also show a cyclic behavior. As a result, the beach may also show cyclic erosion and accretion with large variation due to storms.

Engineering solutions to erosion problems are satisfactory for the average sea conditions where they are designed. They may not function as expected when the situation deviates from ideal design conditions. Any type of hard structure will impose changes in the coastal processes. Revetments or seawalls will change the reflection of waves. The beach face will be modified, which will further modify waves and so on. Groins and detached breakwaters will impose more drastic changes on waves as well as on sediment movement. Because of these reasons, hard structures must be the last option be considered for erosion management. However, there may be cases where such drastic measures can be justifiable. Nourishment of beaches is a softer solution and can be applied in most cases. Management solutions combined with engineering solutions give the optimum results in most cases.

In responding to any erosion problem, answers to the questions found in Table III-3 should be sought for better understanding the situation and to formulate a solution.

TABLE III-3

EXAMPLE QUESTIONS TO FORMULATE A SOLUTION TO EROSION PROBLEMS

1) Is the erosion chronic or seasonal?
2) What is the approximate rate of erosion?
3) Is there an immediate danger to public/private structures from erosion?
4) Will erosion hazard be compounded by inland flooding?
5) Is sufficient material available on the beach for use as a buffer in case of a storm?
6) Is the nearshore seabed dominated by sediment sinks such as deep gullies or deep channels leading offshore?
7) What is the extent of facilities available for evacuating people from endangered areas during a severe event?
8) What are the social, economical and political repercussions of relocation?
9) Can important existing infrastructure be shifted from high risk areas?
10) What are the repercussions of an increased set back?
11) Will extension of the SMA boundary up to a minimum contour help in regulation of development?
12) What types of engineering and management solutions are acceptable from the point of view of land, beach and water use activities?
13) What alternate sites are available for relocation?
14) In cases where public infrastructure is separated from an eroding coast by a strip of private land, is it feasible to purchase the private land?
15) What types of natural sand sources exist in the area for replenishment of eroding areas?
16) Can the overall eroding process effecting the coastal beach be identified before preparing an overall erosion management scheme?
17) To what degree will structures harm public access to the beach, and other coastal resources the area?
18) Is establishment of artificial reefs or promoting coral growth by other means acceptable to the area?

Answers to some of the questions in Table III- will be simple and straightforward, others will be complicated and interdependent. However, the final outcome will give an indication of the best approach possible. Some questions will have more significance in certain areas than others. The issues identified above can be broadly categorized in to two areas:

1) Issues of land ownership, land and water use and the threat of erosion.

2) Issues of Socio/economic and environmental nature.

Sub-issues related to these categories are presented in Table III-4. In This framework, different values must be placed on each sub-issue.

TABLE III-4

EROSION ISSUES

I. LAND OWNERSHIP, LAND AND WATER USE

1. Extent of Erosion
   a. Length of coastline effected at the eroding site.
   b. Land use in the whole stretch.(e.g. Parks, infrastructur, other public facilities, Residential, commercial)
2. Land Ownership and Land Value
   a. Totally owned by public.
   b. Totally owned by one private owner.
   c. Part owned by public and the rest by one private owner.
   d. Owned by several private owners.
   e. Extent of parcels and width of parcel landward.
   f. Land use on the mauka side of the parcels.
   g. Land value.

3. Beach and Water Use
   a. Recreational sports (e.g. surfing, wind surfing, swimming, diving, fishing)
   b. Marinas
   c. Commercial (Harbors, fishing harbors)
   d. Industrial (effluent discharge, cooling water intake and discharge)
   e. Aquaculture (fish ponds,shrimp farms)

II. SOCIO/ECONOMIC AND ENVIRONMENTAL
   a. Potential economic losses (land, infrastructure, structures)
   b. Loss of beach access to the public (shore protection structures, deep escarpments at berm, narrow beach)
   c. Loss of recreational area (beach,surfing areas,swimming areas due to deepening, live reefs effected by deposition)
   d. Loss of scenic value
   e. Changes in the environment (wave patterns, currents, sediment movement and resulting effect on ecosystem)

In order to develop guidelines for decision making, an attempt is made to quantify losses to private and public parties from impacts arising from erosion. Generally, it is very difficult to set down fixed procedures for making erosion management decisions because issues are usually complicated by the land value, land ownership and socio/economic impacts. It should be realized that in a dynamic zone such as the coastline, a degree of flexibility is needed on the part of both the private individuals and regulatory personnel. Methods to quantify positive and negative impacts are discussed below. This procedure should be considered a starting point and should be modified later.

CASE EXAMPLE 1: EROSION OF PARKS AND RECREATIONAL AREAS

The loss can be divided into two parts:

1) Economic loss due to lost land.

   - This is relatively straightforward and can be quantified by multiplying the expected yearly land area loss by the average value per square foot. Any structures that may be partly or completely lost due to erosion may also be included. The replacement cost should be used as the economic loss.

2) Reduction of the recreational capacity of the park land lost by erosion.

   - Value will vary from place to place depending on the indirect economic importance of the facility from the point of view of the tourist and recreation industry.

   - In general, people tend to use the strip of land closest to the beach for recreational purposes. This can be valued by using the average number of person-hours of recreations provided by the facility over a period of one year. In this exercise a value of 50 to 100 feet will be reasonable. By assuming a value for a person-hour of recreation provided by the park, and spreading the total over the most used strip, a recreational value per square foot can be estimated. Loss of recreational area from reconstruction of destroyed facilities should also be calculated on the same basis and added to the total loss.

The two components discussed will give a total loss from erosion. Construction cost for protection of the coast in this example can be weighed against the total loss calculated over the design life-time of the structure. Any negative impact like erosion in front of the wall can also be quantified from the loss of recreational capacity. Values for picnicking, surfing, swimming, and beach activities can be estimated; values will become more accurate as more data is accumulated.

CASE EXAMPLE II: EROSION OF PRIVATE LAND

The same approach can be used in cases where protection of expensive coastal land threatens the recreational areas available to the public. In this case the following issues should be considered:

1) Loss to private land owner.
2) Loss of recreational beach area due to structures.
3) Possible loss of water recreational areas due to structures.
4) Possible land and recreational area loss to adjacent areas.
5) Partial compensation of public cost by private owners by nourishing beach in front of structure over a period that will be determined by the regulatory authority.

In the case of a long stretch with multiple owners, construction of independent structures for protection of individual parcels should be discouraged because this type of structures is difficult to include in a future scheme designed to protect the whole stretch. The affected residents should be encouraged to participate in a total scheme designed to protect the whole stretch from erosion.

IV. FUTURE MANAGEMENT CONCEPTS

Future concepts in erosion management are provided only for the purpose of encouraging new and innovative thinking. Ideas put forth may not be possible under existing legal, social and technical conditions. Additionally, new ideas sometimes bring new problems. However, at the risk of being misunderstood, we provide the following concepts.

In the future we expect coastal erosion problems to be dominated by two types of issues: social and environmental. Social issues will result from increased competition for limited resources. We are seeing our first view of this in 1990 with Hanauma Bay. As a result of the bay's overuse, the City of Honolulu is restricting activities. Environmental issues include sealevel rise and other effects of global warming. Global warming and the resulting sealevel rise is expected to have a major impact on coastal beaches in the far future. If we do not look too far into the future and address erosion only, the following suggestions would either provide financial resources or new planning schemes to deal with erosion problems.

Ongoing beach nourishment
A state funded beach nourishment program that operated all year on all islands would dramatically reduce the cost per unit length to re-nourish beaches. It would address major environmental and public concerns associated with structural solutions, e.g., destruction of habitat, beach access, etc. It could operate with blanket permit authority, perhaps through the "Office of Beaches."

Special tax for beach residences/beach users

Modification to the existing property tax system could be implemented, e.g, a tax could be levied on coastal real estate. Perhaps, a percent of existing property tax could be used for beach maintenance and repairs. Another approach would be to include a use tax for those people (e.g., tourists) that use the beach for recreational purposes.

Impact fee for coastal structures

The construction of any structure along the coastline could carry am impact fee that would be assessed in proportion to the impact on the related issues, e.g., environment, public access, recreational value.

Cost sharing with state and county governments

The expense of beach repair and maintenance could be shared by the coastal land owner in proportion to the real estate value, e.g., annual re-nourishment of beaches.

Improvement districts

Improvement districts would enable shore protection and repair activities to be performed by a group of private land owners. If the group were sufficiently large and addressed a continuous stretch of coastline, a benefit would be bestowed to the public because the impact from the collective efforts would be less than the sum of impacts from individual land owners. Additionally, cost would be reduced.

State parks on all beaches

The State could condemn all coastal lands and create a beach belt that would surround the island. The state would have total control over all coastal erosion and maintenance responsibilities. This may be necessary if global sealevel rise becomes a major problem.

V. CONCLUSIONS AND RECOMMENDATIONS

The current regulatory scheme addresses shoreline management in a piecemeal fashion, including inconsistent management approaches between the state and county governments, lack of uniform policy guidelines, lack of overall planning and the overall complexity of the regulatory process. Of the various needs that exist with respect to coastal erosion management, a lack of information is the key shortcoming that is the most disabling. It prevents the clear determination of policy as well as the consistent execution of existing rules and regulations.

We recommend the mission statement of the Erosion Management Program (EMP) to be "...conserve beaches and minimize erosion." The first and foremost mission goal that needs to be addressed is the collection of information. Other related concerns, including planning/regulation and fiscal/administration will become more focused as information is gathered. Without adequate information, all other related management concerns and regulatory schemes become considerably weakened.

The various types of information collected and evaluated in this project were considered from the point of view of coastal hazards and erosion management in Hawaii. Based on this information we draw the following conclusions and recommendations.

1) INFORMATION CONCLUSIONS:

- In general, coastal land is used as a recreational resource in Hawaii. It has a clear economic value because of the tourist industry. Development pressure within this area is high; therefore, a real danger exists for damaging the environment irreversibly. Management decisions require, at a minimum information on land loss rates. This type of data can only be obtained by long-term monitoring.
- For purposes of calculating past land loss rates, historical maps are needed for baseline information. The most appropriate maps that can be used for this purpose are the National Ocean Survey Topographic (NOS"T") maps.
- In spite of the disadvantages of aerial photographs for calculating shoreline changes, it is clearly the most inexpensive approach for monitoring long coastlines.
- In areas where land loss rates are comparatively low, but important economically, monitoring with aerial photography has to be supplemented with field surveys at least in a few selected places.
- Computer assisted comparison methods are most appropriate for monitoring coastal changes in undeveloped areas. Results may not be accurate enough for making management decisions in highly built-up areas.

2) PLANNING CONCLUSIONS:

- o In past studies, different boundaries have been used for monitoring coastline changes. For Hawaii, the most appropriate boundary is the vegetation line.
- o There is a shortage of data on the coastal zone for decision making.
- o At present, there is a lack of overall comprehensive shoreline management planning and guidelines for decision making.
- o Regulatory process for obtaining permits for activities in the coastal zone are too complicated. This prompts the public to ignore rules.

3) RESOURCE MANAGEMENT CONCLUSIONS:

- o Neither the state nor the counties have sufficient man power or resources to effectively manage coastal erosion problems. This is reflected in the number of illegal, and inadequately designed protective structures constructed by land owners.

- o Problems regarding shoreline encroachments and illegal structures already exist in Oahu. shoreline certification rules complicate the resolution of disputes on encroachment and illegal structures.

- o The certified shoreline, which is the boundary between the conservation district and SMA, is defined as the vegetation line and is subjective and depends on to individual judgment.

The study brought out many shortcomings in the present status of managing erosion in Hawaii. The following recommendations are made as a first step to ease the situation and to enable decision making on issues in this area more streamlined.

1) INFORMATIONAL RECOMMENDATIONS:

- o Establish a data base for the State of Hawaii, including oceanographic, topographic, land and water use data for the coastal zone. Compile data already available with Federal, State, County, or private organizations.

- o Use aerial surveys and a computer aided digitizing method for monitoring the total coastline of Hawaii. This study should be supplemented by shoreline surveys at selected high risk locations for comparison purposes. These monitoring activities should be repeated every five years.

- o Prioritize and coordinate federal, state and county erosion management funding to develop a comprehensive data base on coastal areas statewide.

2) PLANNING RECOMMENDATIONS:

- o Define the certified shoreline by state coordinates and tie it to already existing survey monuments so that this line can be set out uniquely. The line needs to be revised continuously as erosion occurs.

- o Simplify permit process and inform coastal land users regarding the permit requirements and the procedures to follow for proposed activities in this area.

- o Draw up a master plan for erosion management for the whole state. The plan should address the nature of the erosion problem, causes for erosion, problem assessment for different areas and recommendations for the immediate, medium-term and long-term mitigative activities.

- o Develop a comprehensive coastal erosion plan for the state. Since coastal erosion issues affect other pertinent shoreline issues, the coastal erosion plan would be one component of a shoreline plan.

- o Consolidate jurisdiction over the shoreline area to place the bulk of the regulatory powers in one state agency. The most logical way to develop this authority may be to establish a separate division or "Office of Beaches" within an existing agency that already handles these matters, such as the Department of Land and Natural

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